Analysis of MEG relating to subjective preference of visual motion stimuli

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***Abstract*- The aim of this study is to identify the relationship between subjective preference and the human brain responses to visual motion under changing its period. First, preference judgments using the paired-comparison method for sinusoidal movements of a single circular target in horizontal direction were performed. Then, MEG data were recorded during presentations of the most preferred and the least preferred moving stimuli. From the initial delay range of ACF of the alpha wave, the effective duration (τ_e) was analyzed. Results show that the stimulus with most preferred periods has a greater value of τ_e than that with least preferred periods at the occipital area, especially in the left hemisphere.**

***Keywords* - MEG, Motion stimuli, Alpha waves, Autocorrelation function, Subjective preference**

I. INTRODUCTION

The living environment is composed of elements involving spatial and temporal features. We intend to consider both of them to design the comfortable environment. Ando, Johnson and Bosworth suggested an approach, interested in time perception, to an environment design that has focused upon the spatial and temporal characteristics of life in physical environments. They also revealed a possibility of developing a correlation between brain activities and subjective preference for environmental planning [1]. Thus, we may say that it needs to be cleared the relationship between physical factors and physiological responses for subjective evaluations of the environment.

In a sound field, the human auditory-brain system characterized by autocorrelation function (ACF) and interaural cross-correlation function (IACF) and specialization of cerebral hemispheres has been well accepted for the subjective evaluations [2]. Ando and Chen and Chen and Ando developed a method of using the autocorrelation function (ACF) to analyze brain waves [3-4]. They analyzed the effective duration of the envelope of the normalized ACF (τ_e) of the alpha waves under changing the delay time of the single reflection (Δt_1) and the subsequent reverberation time (T_{sub}), which are temporal factors. Their results showed that τ_e of the alpha waves is longer at the preferred conditions of these temporal factors. In addition, Chen, Ryugo, and Ando investigated the relationship between subjective preference and the ACF of α-waves responding to the tempo of a noise burst [5]. Their results showed that τ_e of the alpha waves is longer for the preferred tempo of noise burst.

Accordingly, it seems possible to apply these theory into a visual field, and that subjective preference of visual stimuli is reflected in the human brain activity and physiological responses. In a visual perception, only few attempt have so far been made at the human visual-brain system, especially at movement. Moreover no studies including physiological responses have ever tried.

The aim of this study is to identify the relationship between subjective preference (primitive response) and the human brain responses to visual motion under changing its period. In this study, a single circular target moving horizontally was displayed. At first, subjective preference judgments using the paired-comparison method were performed. From the results of the scale value of subjective preference, the most preferred and the least preferred periods were selected as paired stimuli for recording MEG data. Then the effective duration of the envelope of the normalized ACF (τ_e) of the α-waves was analyzed to examine whether a relationship exists between the subjective preference and the effective duration (τ_e).

II. METHODOLOGY

1) *Stimuli and Subjects*

The stimulus was a single circular target with sinusoidal movements. The diameter of the target is subtended 1.0 deg of visual angle. The amplitude was fixed 0.5 deg of visual angle. The white target on a black background was displayed on a screen. The period of stimulus was varied at six levels (0.6, 0.8, 1.2, 1.6, 2.0 s). The movement of the stimulus is given by

$$h(t) = A\cos(2\pi \frac{t}{T}) \tag{1}$$

where A is mean amplitude, T is the period of the stimulus. The stimulus projected on a screen placed in a dark chamber by a projector in front of subject's eye position at a distance of 130 cm. And they started to move from right field to left field of the subject. Ten subjects (A-J, two women and eight men, 22-25 years old) all had normal or corrected-to-normal vision.

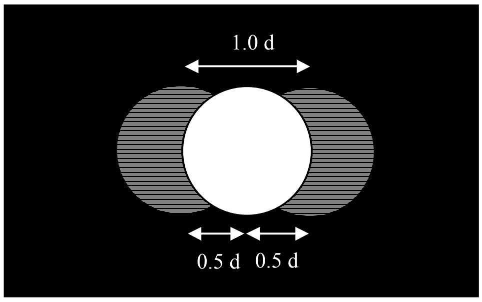

Fig. 1. A single circular target with sinusoidal movement in the horizontal direction as a visual stimulus.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Analysis of MEG Relating to Subjective Preference of Visual Motion Stimuli	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Graduate School of Science and Technology Kobe University Kobe Japan	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

2) *Subjective preference test*

Following the paired-comparison method, subjective preference tests were conducted changing period of the stimulus in a dark chamber. Twenty pairs were combined randomly in a session, and five sessions were conducted for each subject. The interval between the stimuli presentations was 1.0 s and that between comparison pairs lasted 4.0 s in order to allow for subject's responses. Subjects reported which is more subjectively preferred movement by pushing a button. The preference scores of all subjects were evaluated for each period. The scale values of the subjective judgments of each subject were calculated according to Case V of Thurstone's theory [6]. The model of Case V for all data was reconfirmed by a goodness of fit test [7].

Fig. 2 shows global scale values of preferences of ten subjects. The most preferred period was 1.2 s, and least preferred was 0.6 s among ten subjects. Effects of period on the scale values of preference were examined with all 10 subjects using the one-way analysis of variance (ANOVA). The ANOVA results clearly indicate that the effects of period were found to be significant ($p < 0.001$) for all subjects.
The result of goodness of fit for the model had a good match between fitted values and the observed values except that of subject A ($\chi^2 < 12.6 = \chi^2_6(0.05)$).

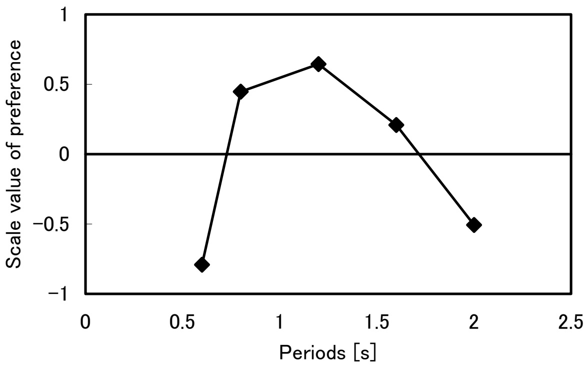

Fig. 2. Scale value of preference as a function of the period of the visual stimulus.

3) *Recording MEG*

Magnetoencephalograms (MEGs) were recorded by using a 122 channel whole-head SQUID (Neuromag-122). The experiment was performed in a magnetically shielded room. The subjects and the conditions of presenting stimuli were the same as for subjective preference test. In order to clear whether the effects on MEGs came from subjective preference or periods, two kinds of pairs were presented. As pair 1, to find a significant effect of subjective preference on MEGs, the most preferred period and the least preferred period were selected as a pair stimuli (Fig. 2, [0.6 and 1.2] s pair). As pair 2, the stimuli having the opposite relationship about periods to pair 1 were chosen (Fig. 2, [1.2 and 2.0] s pair). According to individual differences of the subjective preference, the pairs were set for each subject. The subjects watched the most and the least preferred period alternatively. Each pair was presented successively ten times (one series) with a 1.0 s repetitive interval and three series were conducted for all subjects. Therefore 30 MEG data were recorded in each pair from each subject. The MEGs were filtered from 0.1 to 30.0 Hz and digitized with sampling rate of 400 Hz. Fig. 3 shows an example of the distribution of MEG signals over the scalp using the whole-head system. The figure shows that the channels at the temporo-occipital area have the stronger amplitude, especially in the left hemisphere. It is for this reason that the visual stimulus started to move from right field of the subject.

To discuss brain activity in relation to the human's behavioral states, Lindsley reported that EEG well corresponds to α-waves which is always shown in relaxed states and is associated with free creative thought [8]. Therefore for further analysis of the effective duration of ACF (τ_e), MEG data were filtered in α-wave ranges (from 8 to 13 Hz).

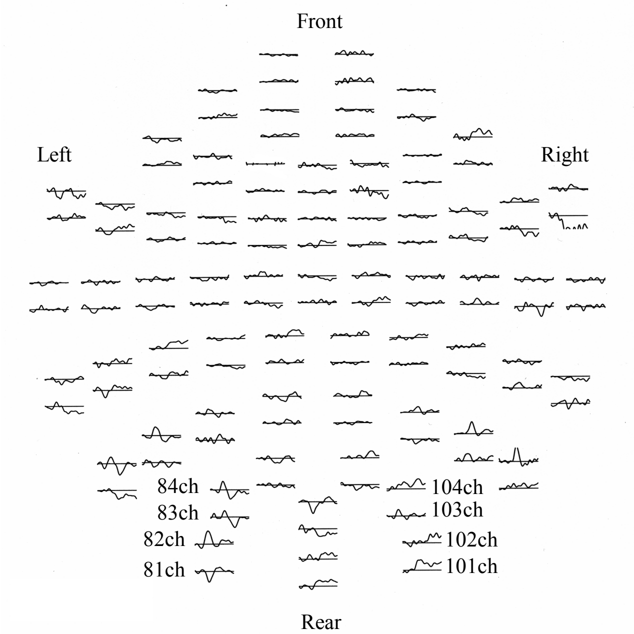

Fig. 3. An example of the average MEG signal from one subject (100 ms prestimulus and 300 ms poststimulus) at all 122 ch during preferred period.
The MEGs were filtered (0.1-30.0 Hz) and digitized with sampling at a rate of 400 Hz.

4) *Autocorrelation function (ACF) Analysis*

The autocorrelation function (ACF) and power density spectrum mathematically contain the same information. Four physical factors are obtained from the ACF [2]: (1) energy represented at the origin of the delay, $\Phi(0)$; (2) effective duration of the envelope of the normalized ACF, τ_e, representing a kind of repetitive feature containing the signal itself; (3, 4) fine structure, including peaks and dips with their delays, the delay time and amplitude of the first peak-namely, τ_1 and ϕ_1.

The normalized ACF is defined by

$$\phi(\tau) = \frac{\Phi(\tau)}{\Phi(0)}, \quad (2)$$

where

$$\Phi(\tau) = \frac{1}{2T}\int_{-T}^{+T}\alpha(t)\alpha(t+\tau)dt; \quad (3)$$

where 2T is the integral interval, τ is the time delay, and $\alpha(t)$ is the alpha wave of an MEG.

Fig. 4 demonstrates an example of the logarithm of the absolute value of the ACF plotted as a function of the delay time. The envelope decay of the initial part of the ACF can be fitted by a straight line in a range from 0 dB to -5 dB, and the effective duration τ_e of the ACF can be easily obtained from the decay rate extrapolated at -10 dB [3]. The integration time duration (2T) was set at 2.5 s for our ACF analysis of τ_e, which is the shortest duration needed to make subjective preference judgments [3]. Calculating τ_e of ACF in alpha-wave range, the occipital area in both left and right hemispheres of each subject's head (Fig. 3 81-84 ch, 101-104 ch) was selected.

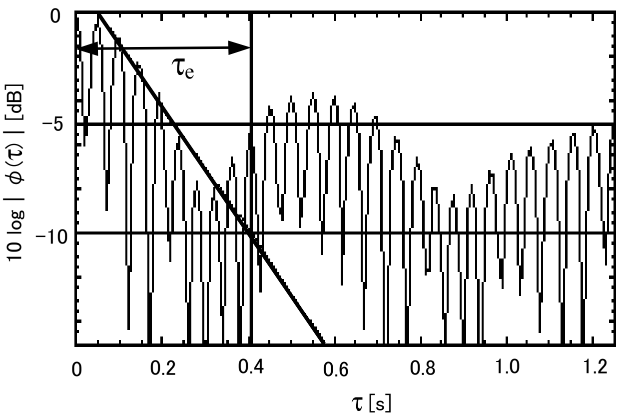

Fig. 4. Definition of the effective duration of ACF (τ_e).

III. Results

Subject A and B were omitted from the results because subject A didn't have a confident result to a goodness of fit test for the scale values of the subjective judgments.

A. Values of τ_e in alpha-wave range

The ratios of the averaged τ_e values at most preferred stimuli to those at least preferred stimuli for each subject were calculated to compare with the differences in scale values of preference. Fig. 5 shows the typical examples in both kinds of pairs.

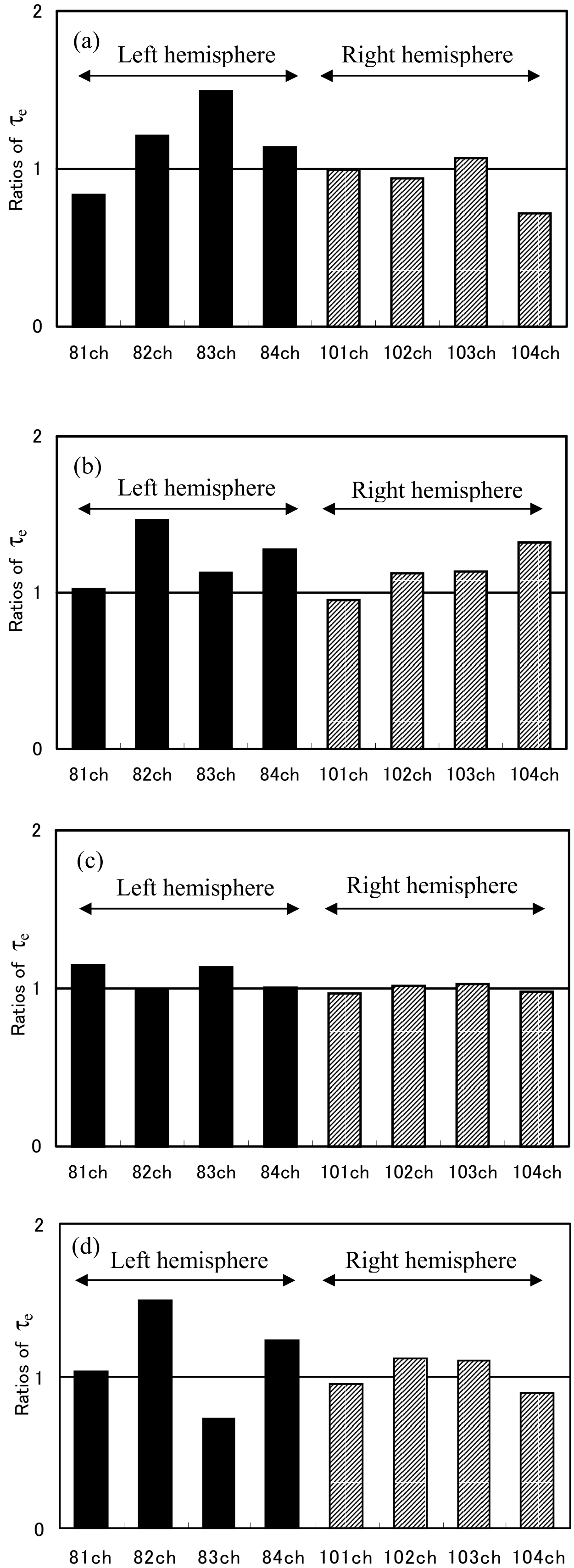

Fig. 5. Ratios of τ_e value in α-wave range which responded to the change of the period for four subjects.
[τ_e value at preferred period] / [τ_e value at non preferred period]
(a) Subject D at pair 1 (b) Subject E at pair 2
(c) Subject H at pair 1 (d) Subject I at pair 1

B. Hemispheric Dominance

Fig. 6 shows the differences between the ratio of the averaged τ_e of the channel at which it changed the most largely in the left hemisphere when two stimuli were presenting and that in the right hemisphere for each subject except A and B.

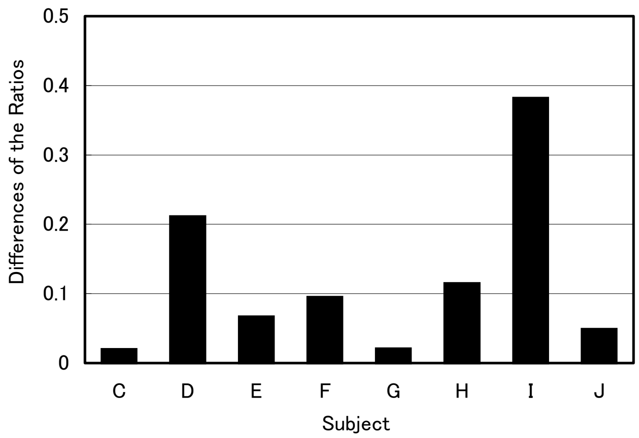

Fig. 6. Differences between the ratios that changed the most largely in the left hemisphere and those in the right hemisphere at pair 1

IV. Discussion

The ratios of the averaged τ_e values at most preferred stimuli to those at least preferred stimuli tended to be greater than unity at the occipital area, especially in the left hemisphere during presentations of both kinds of pairs as shown in Fig. 5. The value of τ_e of ACF for α-waves is prolonged with a certain degree of coherent at the preferred condition. This may be interpreted in such a way that a similar repetitive feature in the α-waves is evoked due to comfortable relaxation that may be repeated in the mind. However, large individual differences were shown among all subjects. There are probably several causes for this result, one is the individual difference of sensitivity to the movement of stimulus. Another is due to area of analysis, because the numbers of MEG channel don't located on the same positions of subject's cortex. Thus, there is room for further investigation on the area of analysis.

Fig. 6 was shown in order to discuss hemisphere dominance. The ratio of the averaged τ_e values at most preferred stimuli to those at least preferred stimuli indicates a degree of changes of τ_e for two stimuli. If the values of τ_e at two stimuli are the same, the ratio is unity. As the ratio is apart from unity, it can be regarded that the values of τ_e changed greatly. Therefore the ratio that changed the most largely in the left hemisphere and that in the right hemisphere were selected, then the differences between them were investigated. It is obvious for all eight subjects that the differences are consistently greater than zero. So it can be said that the left hemisphere of the subject was activated greatly for visual motion under changing its period ($p < 0.01$). This may indicate the left hemisphere dominance for changing periods. The above mention might be explained by specialization of human brain. As is well known, our left cerebral hemisphere is associated with the temporal features of the environment, and the right hemisphere is associated with spatial features [2]. This tendency of our result in visual field is similar to previous studied in a sound field. When the spatial factor, the listening level of a continuous speech signal was changed, the right hemisphere was activated significantly [9]. And when the temporal factors, the noise-burst tempo, the delay time of the single reflection ($\Delta t1$), and the subsequence reverberation time (T_{sub}), were changed, the left hemisphere was activated significantly [2-4]. The result of our experiment in a visual field is considered to be due to changing the temporal factor, the period of visual stimulus.

V. Conclusion

At the preferred period of the motion stimulus, values of τ_e in alpha wave range are longer than those at the least preferred period at the occipital area, especially in the left hemisphere. In regard to the hemispheric specialization, the left hemisphere is activated when the periods of the motion stimuli are changed.

Acknowledgment

This research was supported by a Research Fellowship from the Japan Society for the Promotion of Science for Young Scientists.

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